PTO 03-0417

CY=DE DATE=19990602 KIND=U1
PN=29902348

MICROMECHANICAL OPTICAL MOVEMENT DEVICE
[Mikromechanische optische Bewegungseinrichtung]

CMS Mikrosysteme GmbH

UNITED STATES PATENT AND TRADEMARK OFFICE
Washington, D.C. November 2002

Translated by: FLS, Inc.

PUBLICATION COUNTRY	(10):	DE
DOCUMENT NUMBER	(11):	29902348
DOCUMENT KIND	(12):	U1
	(13):	Utility Model
PUBLICATION DATE	(43):	19990602
PUBLICATION DATE	(45):	
APPLICATION NUMBER	(21):	29902348.6
APPLICATION DATE	(22):	19990211
ADDITION TO	(61):	
INTERNATIONAL CLASSIFICATION	(51):	G 02 B 26/00
DOMESTIC CLASSIFICATION	(52):	
PRIORITY COUNTRY	(33):	
PRIORITY NUMBER	(31):	
PRIORITY DATE	(32):	
INVENTOR	(72):	None Indicated
APPLICANT	(71):	CMS Mikrosysteme GmbH
TITLE	(54):	MICROMECHANICAL OPTICAL MOVEMENT DEVICE
FOREIGN TITLE	[54A]:	Mikromechanische optische Bewegungseinrichtung

SPECIFICATIONS /1*

This invention relates to a micromechanical optical movement device as recited in the precharacterizing part of Claim 1.

Devices for one-, two-, and three-dimensional positioning in the micrometer range are known in numerous variations from a number of publications. Drives for such devices are based on electrostatic, electrodynamic, piezoelectric, or other physical principles.

DE OS 4229507 (Micromechanical 3-D Actuator) describes a micromechanical actuator whose moving part is preferably positioned by electrostatic forces. First of all, the actuator is freely mounted by means of spring devices and a frame opposite a base plate and, secondly, a sphere is located between actuator and base plate. In the former case, three-dimensional motion by the actuator is possible. The third dimension, in the form of the distance between the actuator and the base plate, is determined by the electrostatic forces between the base plate and the actuator. However, the actuator is tilted by the same forces that move it in the other two dimensions, these motions cannot be made completely independent of one another in the static and dynamic case. In the

*Numbers in the margin indicate pagination in the foreign text.

second case, no movement in the third dimension is possible.

The object of the invention presented in Claim 1 is to create a movement device that produces a three-dimensional deflection.

This object is achieved by the characteristics presented in Claim 1.

The micromechanical optical movement device is characterized /2 in that a plate can be moved adjustably and controllably in three dimensions. Compared to conventional devices, the distance between plate and base plate is also adjustable. The electrostatic or electrodynamic forces assure a fixed plate position with respect to the base plate in the adjustable device. By using silicon at least for the plate and the spring mechanism, it is possible to apply the conventional production methods of microelectronics and micromechanics. At the same time, silicon is characterized by its material properties, particularly its lack of fatigue.

An additional advantage is the fact that the motion of the plate with respect to the base plate occurs both statically and dynamically. Both variations of this movement permit a variety of applications.

In the former case, the distance is adjusted in accordance with the geometry of the plate and the spring mechanism. Thus, it

is possible to operate the plate and its spring device by dynamic movements at resonance. Thus, differences in geometric measurements of the movement device caused by manufacturing tolerances can be compensated.

In the second case, the distance between the plate and the base plate of the movement device is variable both when the plate is standing still and when it is in motion with respect to the base plate. If the plate is made in the form of a mirror, in addition to the targeted and directed deflection of light beams incident on the mirror surface, it is also possible to switch to an additional surface, without changing the distance between the mirror surface and the target surface. At the same time, the possibility of fading out is offered, whereby a position of incidence of the light beam reflected on the mirror surface outside the mirror surface is not used.

Advantageous embodiments of the invention are presented in Claims 2 through 16.

The enhancement of the invention in accordance with Claim 2 supports operation of the movement device at resonance.

A column made of a piezoelectric material, as indicated in /3 the enhancement presented in Claim 3, presents a simple possibility

for changing the length of the column itself. Piezoelectric materials are characterized by a change in their geometric dimensions when an electric voltage is applied. The geometric dimensions change in all directions. Depending on the polarization, one of these dimensions is the preferred direction with the greatest change in length. Consequently, a change in length is preferably produced by stacking several parts one upon the other in one direction, where the changes in the parts are summed in the stacking direction.

Particularly favorable is a column whose parts have a circular cross section. In this way, the parts change their radial extension and their thickness when a voltage is applied. The parts are foils that are stacked as segments, one on the other.

Favorable embodiments of the columns, in accordance with Claim 4, are a cylinder, a cuboid, a pyramid, a cone, a stepped cone, or a stepped pyramid.

In accordance with the enhancement in Claims 5 and 6, the column may be attached to the base plate or the plate. The other end of the column is preferably a spherical cap, a paraboloid of rotation, or a cone.

When the column is implemented as a stepped cone or stepped pyramid, surfaces are arranged parallel to the plate or base plate that are advantageously made in accordance with Claim 7 as supports for electrodes or electrical coil devices. There is a small distance between plate and electrode or coil device, compared to the distance between plate and base plate, so that low voltages or electrical currents are needed to produce an identical deflection.

The enhancement in Claim 8 results in a device with which large changes in length are possible. It makes use of the differential expansion during heating of connected materials that cause bending of flat parts. Two such flat parts arranged /4 parallel to each other connected at one end by a crosspiece produce a change in length in a line of symmetry. There is no change in position in the point of contact between the device and the mounting point of the plate or the base plate.

Flat parts that change their dimensions when a voltage is applied produce the same effect. This means preferably piezoelectric materials, where the change in length occurs in all directions of the flat parts.

According to the enhancement in Claim 9, the column is connected to a linear drive or it is the moved part of the linear

drive. At the same time, the linear drive is located in an opening in the base plate or the column or moved part of the linear drive is inserted into an opening in the base plate. This arrangement permits particularly large regulating distances between plate and base plate. Particularly advantageous is the embodiment in which the base plate is designed as the fixed part of the linear drive itself. Favorable embodiments of a linear drive, as indicated in Claim 10, are a piezoelectric microstepper motor, a magnetostrictive microstepper motor, or a strain bar motor. With a strain bar motor, discrete changes in length may be achieved by utilizing the thermal expansion of solid materials. The heat may be added, for example, by high-frequency heating.

It is also possible to increase the distance between plate and base plate, so that greater deflection angles may be achieved. Moreover, large regulating distances may be achieved with the enhancement in Claim 11, where the column is a part of the lifting device or is connected to the moved part of the lifting device.

With lever device in accordance with Claim 12, in particular, very small changes in the dimensions of a body can be used to produce a relatively large travel/lift. For this purpose, the body is connected to the shorter lever arm and the column to the longer

one. The thermal expansion of solids or the change in length of bodies when a voltage is applied my be utilized.

With the enhancement of the invention in Claim 13, a light /5 transmitter or light detector is placed at the center of the plate. With this arrangement, light beams can be transmitted and reflected at the same time. Scattered light can be measured by positioning a light receiver.

In accordance with the enhancement of the invention in Claim 14, the spring device in the form of several meander-shaped bars provides large deflections and assures equal restoring forces in all three directions.

The enhancement in Claim 15 is a swiveling mirror.

In accordance with the enhancement of the invention in Claim 16, the surface of the base plate facing the plate provides a favorable placement of the electrodes or of the at least one coil device.

Embodiments of the invention are shown in the drawings and will be described in greater detail below.

They show:

Figure 1: a top view of the micromechanical optical movement device;

Figure 2: a cross section of an adjustable device made in the form of a cylinder, consisting of a plurality of disks of piezoelectric material;

Figure 3: a cross section of an adjustable device made in the form of a stepped cone, consisting of a plurality of disks of piezoelectric material;

Figure 4: a cross section, with an adjustable device made of several flat parts;

Figure 5: a cross section, with a piezoelectric microstepper motor as the adjustable device;

Figure 5: a cross section, with a bimetal as a lifting device.

Exemplary Embodiment 1 /6

In a first embodiment, the micromechanical optical movement device consists of a base plate **4** and a movable square plate **1** facing it at a distance that is connected to a surrounding frame **3** by means of four spring devices **2a, 2b, 2c, 2d** at the center of its sides. Each spring device **2a, 2b, 2c, 2d** consists of meander-shaped bars, whereby three bars are parallel to the side edge of the plate and four bars form connectors at right angles to the edge. The middle bar of those running parallel to the edge is twice the length of the other two bars. Figure 1 shows the

principle involved in such a device. Additional geometric arrangements of the bars are possible in special meander shapes that provide equal restoring forces in all three directions.

Plate **1** including spring devices **2a, 2b, 2c, 2d** and frame **3** consist of silicon.

Moreover, plate **1**, spring devices **2a, 2b, 2c, 2d**, and frame **3** are arranged at a distance from base plate **4**. For this purpose, frame **3** is thicker, appropriate to the distance. The distance is implemented by an additional frame or base plate **4** has a depression corresponding to the distance.

The surface of plate **1** facing base plate **4** has either at least one electrode or a permanent magnetic volume. At the axis of symmetry of plate **1** and between plate **1** and base plate **4** there is a device for adjusting the distance between plate **1** and base plate **4**. The following implementations are given for the adjustable device.

In a first variation, the adjustable device is a column that is made in the form of a cylinder **6**, a pyramid, or a cone. This column is attached either on plate **1** or base plate **4**. Figure 2 shows a cylinder **6** that is attached to base plate **4**. The column is made of disks, where each disk is made of a foil of piezoelectric material and may form an electrical contact. Such materials

include ceramics made, for example, of rare-earth elements or barium titanate. The end of the column that is not attached forms the first part of the point of support of plate **1** opposite base plate **4** and it is a spherical cap **8**, a paraboloid or rotation, or a cone. The second part of the point of support is a depression **5** /7
in plate **1** or base plate **4**. This is advantageously made in the form of a pyramid or frustum of a pyramid.

The following are located on the surface of base plate **4** facing plate **1** or integrated into the base plate:

-electrodes, if there are electrodes on or in plate **1** (electrostatic forces) or

-at least four coil devices, if there is a permanent magnetic volume on plate **1** (electrodynamic forces).

In a second variation the adjustable device is a column made in the form of a stepped cone **7** or a stepped pyramid. This column is attached on either plate **1** or base plate **4** (shown in Figure 3). The column consists of disks, each having a different cross section, so as to form the steps. Each disk is a piece of foil made of a piezoelectric material and may form an electrical contact. Such materials include ceramics made, for example, of rare-earth elements or barium titanate. The end of the column that

is not attached forms the first part of the point of support of plate **1** opposite base plate **4** and it is a spherical cap **8**, a paraboloid or rotation, or a cone. The second part of the point of support is a depression **5** in plate **1** or base plate **4**. This is advantageously made in the form of a pyramid or frustum of a pyramid. Electrodes are placed on the surfaces of the steps facing plate **1** and/or on base plate **4**. At the same time, there are electrodes on the surface of plate **1** facing base plate **4**, so that electrostatic forces can be produced.

In a third variation, the adjustable device consists of two parallel and at least two connected flat parts **9a, 9b** (shown in figure 4). The flat parts **9a, 9b** that are connected together consist of materials that possess different coefficients of thermal expansion. When heated by an electrical current, connected flat parts **9a, 9b** bend.

Parallel flat parts **9a, 9b** are connected to each other by a cross piece **10** at one end of parallel flat parts **9a, 9b**. At least one of the other ends of parallel flat parts **9a, 9b** is provided with a /8
spherical cap **8** or a paraboloid of rotation. For purposes of increasing the distance, spherical cap **8** or the paraboloid of rotation is on a column **13**. There are arranged on at least one of

the surfaces opposite cross piece **10**. Spherical cap **8** or the paraboloid of rotation is at least a first bearing part. The second part of the point of support is a depression **5** in plate **1** and/or base plate **4**. This is advantageously made in the form of a pyramid or frustum of a pyramid. The following are located on the surface of base plate **4** facing plate **1** or integrated into the base plate:

-electrodes, if there are electrodes on or in plate **1** (electrostatic forces) or

-at least four coil devices, if there is a permanent magnetic volume on plate **1** (electrodynamic forces).

In a fourth variation, the adjustable device is a column **13** that is connected to a linear drive or a column-like part of the linear drive itself. In this case, column **13** or the column-like part engages in the middle of plate **1**. The linear drive is located in base plate **4** or is arranged in the surface of base plate **4** facing away from plate **1**. In both cases, base plate **4** has an opening **15** for holding the linear drive or for guiding the moved part in the form of column **13** or the column-like part. The cross section of opening **15** is larger than the cross section of column **13** or of the column-like part.

The linear drive is made in the form of a piezoelectric actuator. It may consist, for example, of three bodies **11a, 11b, 11c** arranged in a row made of a piezoelectric material (shown in Figure 5). The outer bodies **11a, 11c** have identical cross sections, while the middle body **11b** is smaller in cross section. Mutual activation of outer bodies **11a, 11c** in conjunction with mutual activation of middle body **11b**, through an equivalent mutual locking or loosening of outer bodies **11a, 11c** together with the expansion or contraction of middle body **11b**, results in a motion by the three bodies **11a, 11b, 11c** in the correspondingly designed opening **15**. This solution is particularly advantageous since, when not activated, outer bodies **11a, 11c** are jammed in opening **15**. This circumstance is of particular importance when plate **1** is operated at resonance. /9
Activation means the application of a voltage. Bodies **11a, 11b, 11c** move in accordance with the motion of a crawler (inchworm principle). Opening **15** is located in base plate **4** and a column **13** is attached to body **11a**, which is arranged in the direction of plate **1**. Being the first part of a point of support, the end of column **13** made in the form of a spherical cap **8**, a paraboloid of rotation, or a cone.

The second part of the point of support is a depression **5** in plate

1 and/or base plate **4**. This is advantageously made in the form of a pyramid or frustum of a pyramid. The following are located on the surface of base plate **4** facing plate **1** or integrated into the base plate:

-electrodes, if there are electrodes on or in plate **1** (electrostatic forces) or

-at least four coil devices, if there is a permanent magnetic volume on plate **1** (electrodynamic forces).

Of course, it is possible to use other piezoelectric microstepper motors that are connected to the column.

In a fifth variation an electrical lifting device for column **13** is located on the surface of base plate **4** that is facing away from plate **1**. The column is loosely inserted through an opening **15** of equal cross section. Such a lifting device may be, for example, an electrodynamic linear drive, a DC linear motor, a traveling field motor, or a bimetal (shown in Figure 6).

In another embodiment, the lifting device is a lever arrangement. The shorter lever arm is connected to base plate **4** via a body that is variable in at least one of its dimensions. The longer lever arm is connected to column **13**, which is inserted in opening **15**. The fulcrum of the lever arrangement is arranged at a distance from

base plate **4**.

As a first point of support, the end of column **13** is made in the form of a spherical cap **8**, a paraboloid or rotation, or a cone. The second part of the point of support is a depression **5** in plate **1** and/or base plate **4**. This is advantageously made in the form of a pyramid or frustum of a pyramid. The following are located on the surface of base plate **4** facing plate **1** or integrated into the base plate: /10

-electrodes, if there are electrodes on or in plate **1** (electrostatic forces) or

-at least four coil devices, if there is a permanent magnetic volume on plate **1** (electrodynamic forces).

Exemplary Embodiment 2

The micromechanical optical movement device of a second embodiment has the same design as the first embodiment and its first two variations.

The plate, the piezoelectric column, and the base plate have a through opening into which an optical fiber is inserted. The end of the optical fiber is equipped either with a device for receiving a light beam, such as a lens, and/or with a device for producing a light beam, such as a diode laser. The surface of the plate and the

end of the device or devices are arranged in the same plane.

Claims

/11

1. A micromechanical optical movement device comprising a plate that is movably arranged at a distance from a base plate, the plate, first of all, being connected by means of a spring arrangement to a frame surrounding the plate and, secondly, being moved by electrostatic or electrodynamic forces, characterized in that plate **1** is loosely connected to base plate **4** by a device that can adjust the distance between plate **1** and base plate **4**, that, in the direction of base plate **4**, the surface of plate **1** has at least one electrode that can be activated or a volume containing a permanent magnet, and that frame **3** and base plate **4** are arranged at a fixed distance from each other.

2. A micromechanical optical movement device as recited in Claim 1, characterized in that the adjustable device is arranged at the center of plate **1**.

3. A micromechanical optical movement device as recited in Claim 1, characterized in that the adjustable device is a column made of at least one part and of at least one piezoelectric material.

4. A micromechanical optical movement device as recited in Claim 3, characterized in that the column is a cylinder **6**, a cuboid, a pyramid, a cone, a stepped cone **7**, or a stepped pyramid.

5. A micromechanical optical movement device as recited in Claim 4, characterized in that the end of the column that is arranged on plate **1** or the end of the column that is arranged on the base plate is a spherical cap **8**, a paraboloid or rotation, or a cone.

6. A micromechanical optical movement device as recited in Claim 4, characterized in that, first of all, the end of stepped cone **7** or of the stepped pyramid arranged on plate **1** or, secondly, the end of the stepped cone or stepped pyramid arranged on base plate **4** is a pyramid, a paraboloid of rotation, or a spherical cap **8**. /12

7. A micromechanical optical movement device as recited in Claim 4, characterized in that surfaces of stepped cone **7** or of the stepped pyramid parallel to plate **1** or parallel to base plate **4** also serve to support electrodes or electrical coil devices.

8. A micromechanical optical movement device as recited in Claim 1, characterized in that the adjustable device consists of two parallel and at least two connected flat parts **9a, 9b**, that

flat parts **9a, 9b** are connected to each other by a cross piece **10** at one end of parallel flat parts **9a**, that at least one other end of the surface of a flat part **9a** facing away from cross piece **10** is provided with a spherical cap **8** or a paraboloid of rotation, and that the two connected flat parts **9a, 9b** possess different coefficients of thermal expansion or change their dimensions when a voltage is applied.

9. A micromechanical optical movement device as recited in Claim 1, characterized in that the adjustable device comprises a column **13** connected to a linear drive or that column **13** is, at the same time, the moved part of the linear drive and that base plate **4** has an opening **15** that loosely accommodates column **13** and/or the movable part of the linear drive or that base plate **4** is the fixed part of the linear drive.

10. A micromechanical optical movement device as recited in /13
Claim 9, characterized in that the linear drive is a piezoelectric microstepper motor **11**, a magnetostrictive microstepper motor, or a strain bar motor.

11. A micromechanical optical movement device as recited in Claim 1, characterized in that column **13** is connected to a lifting device, that base plate **4** has an opening **15** that loosely

accommodates column **13** and/or the movable part of the lifting device, and that the lifting device is arranged on the surface of base plate **4** that is facing away from plate **1**.

12. A micromechanical optical movement device as recited in Claim 1, characterized in that a lever device is arranged on the surface of base plate **4** facing away from plate **1**, that the fulcrum of the lever device is arranged at a distance from this surface, that preferably the shorter lever arm is connected to base plate **4** by a body that is capable of changing its dimensions, and that column **13** is preferably connected to the longer lever arm.

13. A micromechanical optical movement device as recited in Claim 1, characterized in that plate **1**, the adjustable device, and base plate **4** have a through opening and that a device for transmitting and/or receiving a light beam is arranged in the opening.

14. A micromechanical optical movement device as recited in Claim 1, characterized in that spring device **2** consists of meander-shaped bars.

15. A micromechanical optical movement device as recited in Claim 1, characterized in that the surface of the plate facing away from the base plate is provided with a layer that reflects light /<u>14</u>

beams.

16. A micromechanical optical movement device as recited in Claim 1, characterized in that the surface of the base plate facing the plate has or is at least one electrode or a coil arrangement.

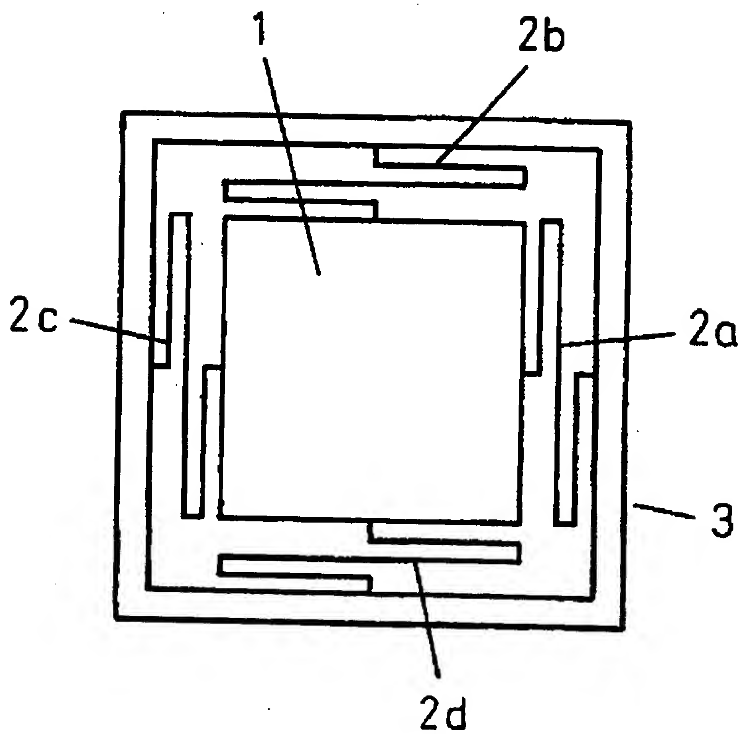

Fig. 1

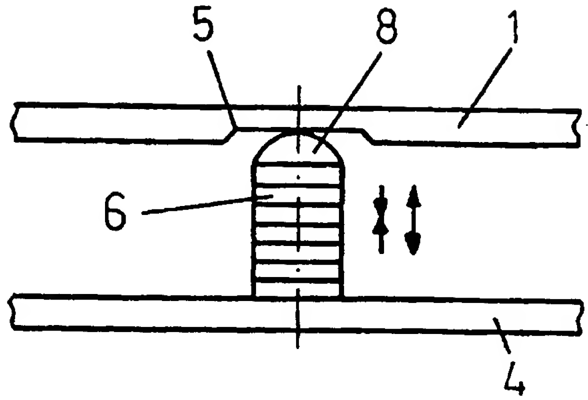

Fig. 2

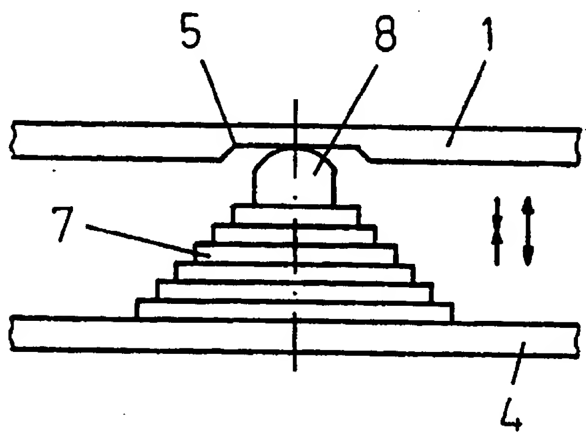

Fig. 3

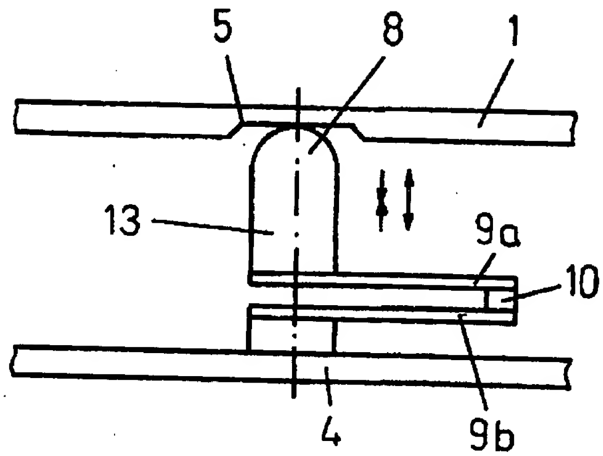

Fig. 4

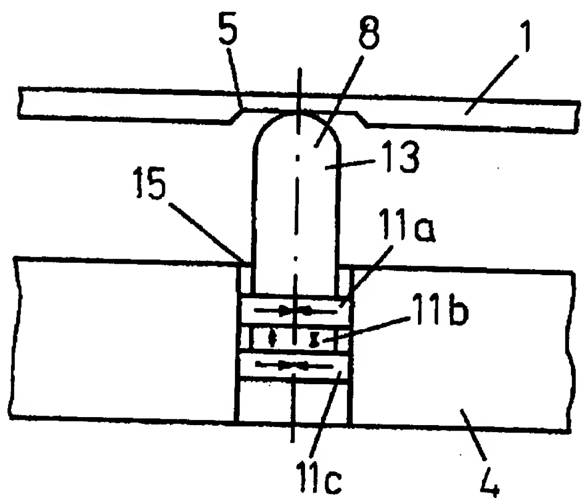

Fig. 5

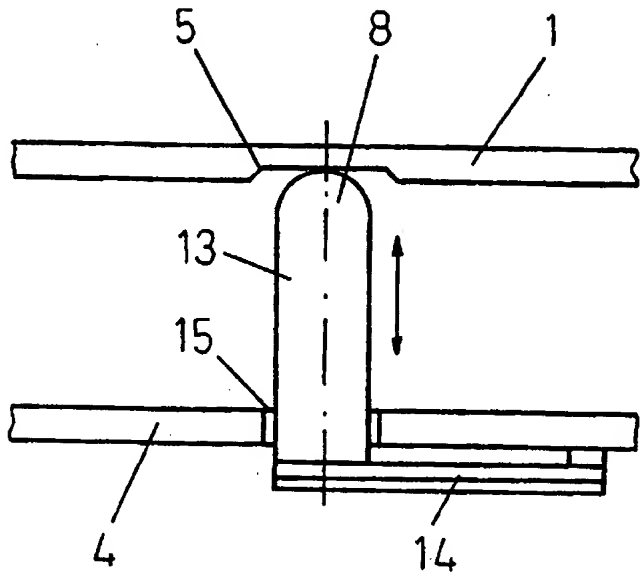

Fig. 6